SISTEMAS E REDES MULTISERVIÇO

Chapter 3

Technologies in Access Networks

ACCESS NETWORK

Objectives:

Understand the architecture of ADSL, CATV, GPON and 4G/ 5G mobile networks

Identify debits for each Internet access technology

Identify advantages and limitations and each technology

Identify the technology that best adapts to the technical and financial needs of clients in concrete situations.

Topics:

ADSL

CATV networks

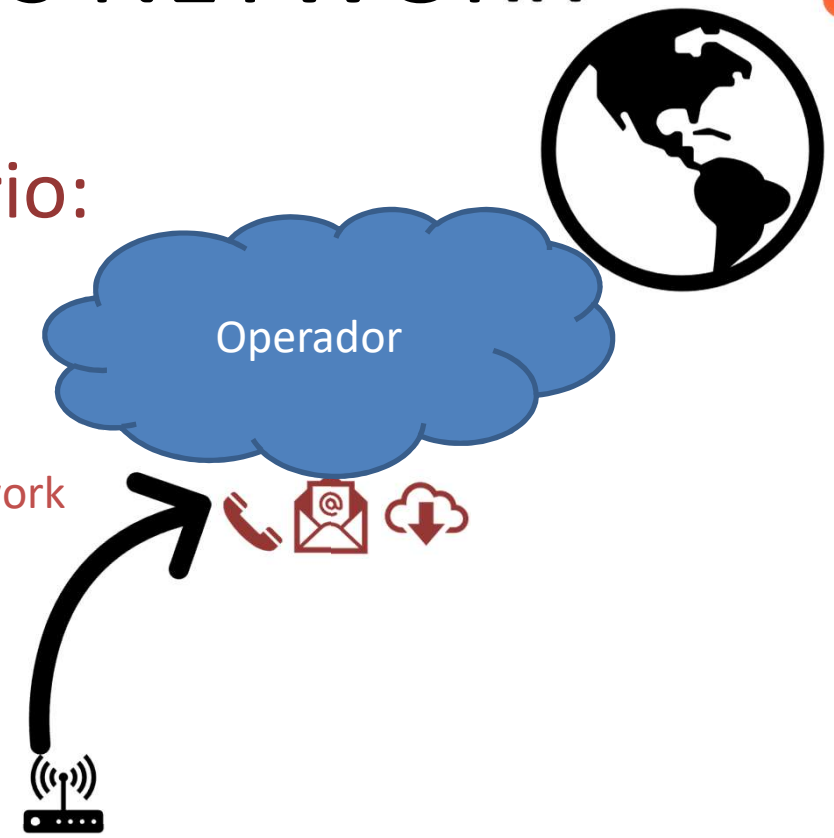
GPON

4G - LTE

5G

ACCESS NETWORK

Current Scenario:



Multi-service Access Network

ADSL up to 24 Mbps
CATV up to 300Mbps
GPON fiber up to 1Gbps
4G Mobile up to 300Mps

LAN – Local Network

Ethernet - 1Gbps
WiFi - 300Mbps ou 1,3Gbps

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DSL ACCESS

The implementation of Internet access in telephone lines with DSL (Digital Subscriver Line) technology had technical and commercial motivations:

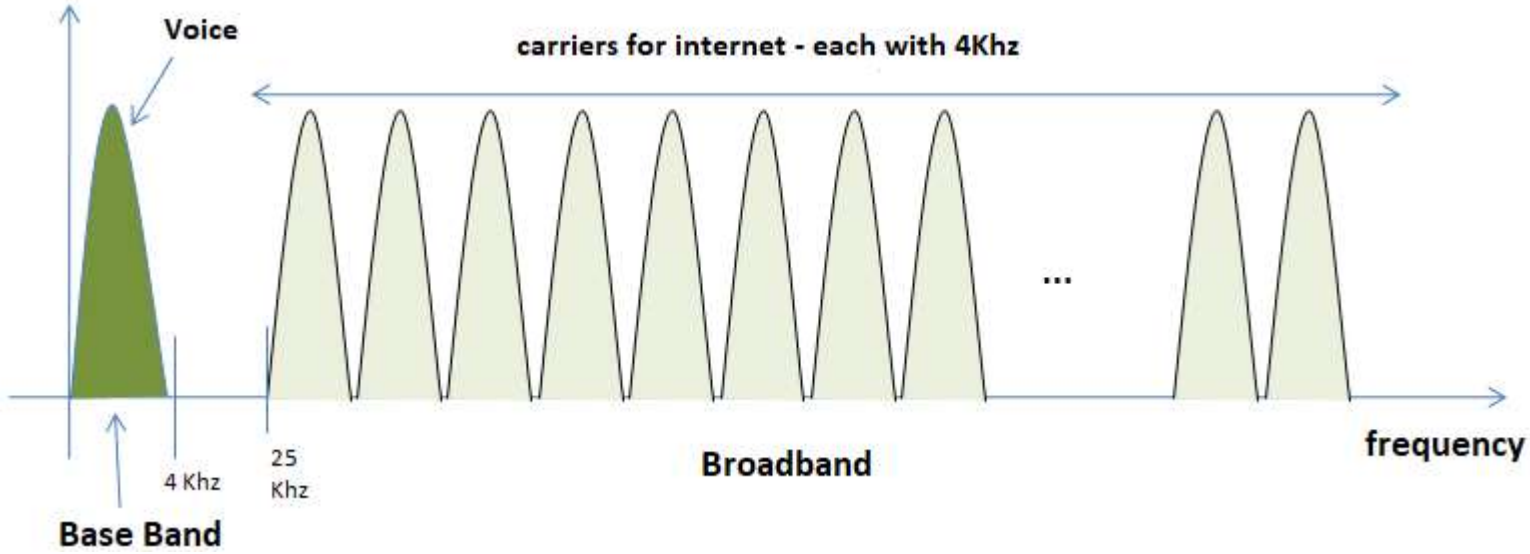
Take advantage of the available bandwidth not occupied by voice on the copper wires of the telephone network.

Stop disassembling access through high-speed Internet access offerings to combat cable operators

It was with the DSL that broadband began to be used.

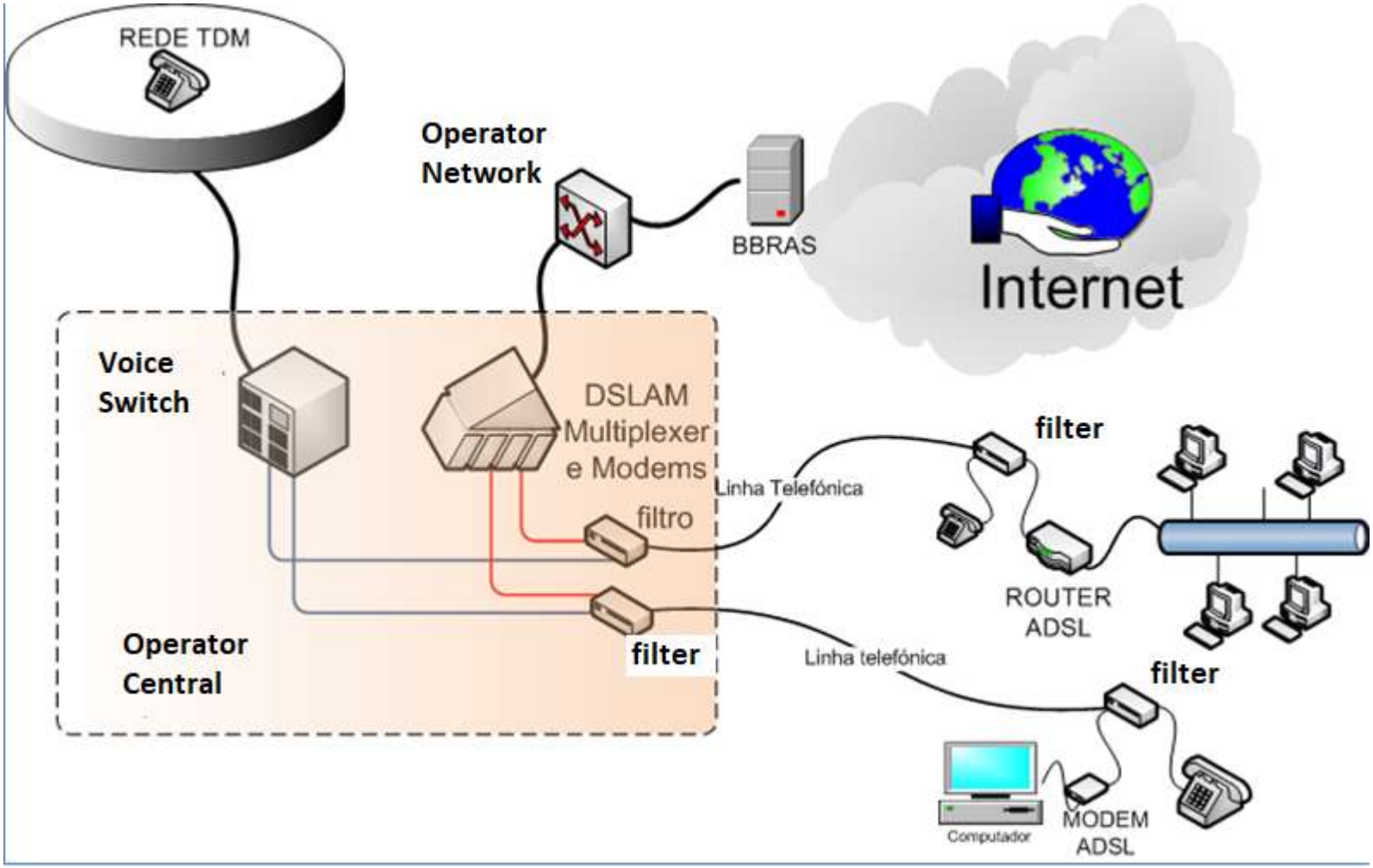
ACESSO DSL

Internet transmission on copper telephone lines is made by injecting digital signals into multiple carriers with frequencies higher than the base band (voice):



Lower broadband data carriers are used for upload, while top data are for download. Each DSL variant use different quantities of carriers for upload or download.

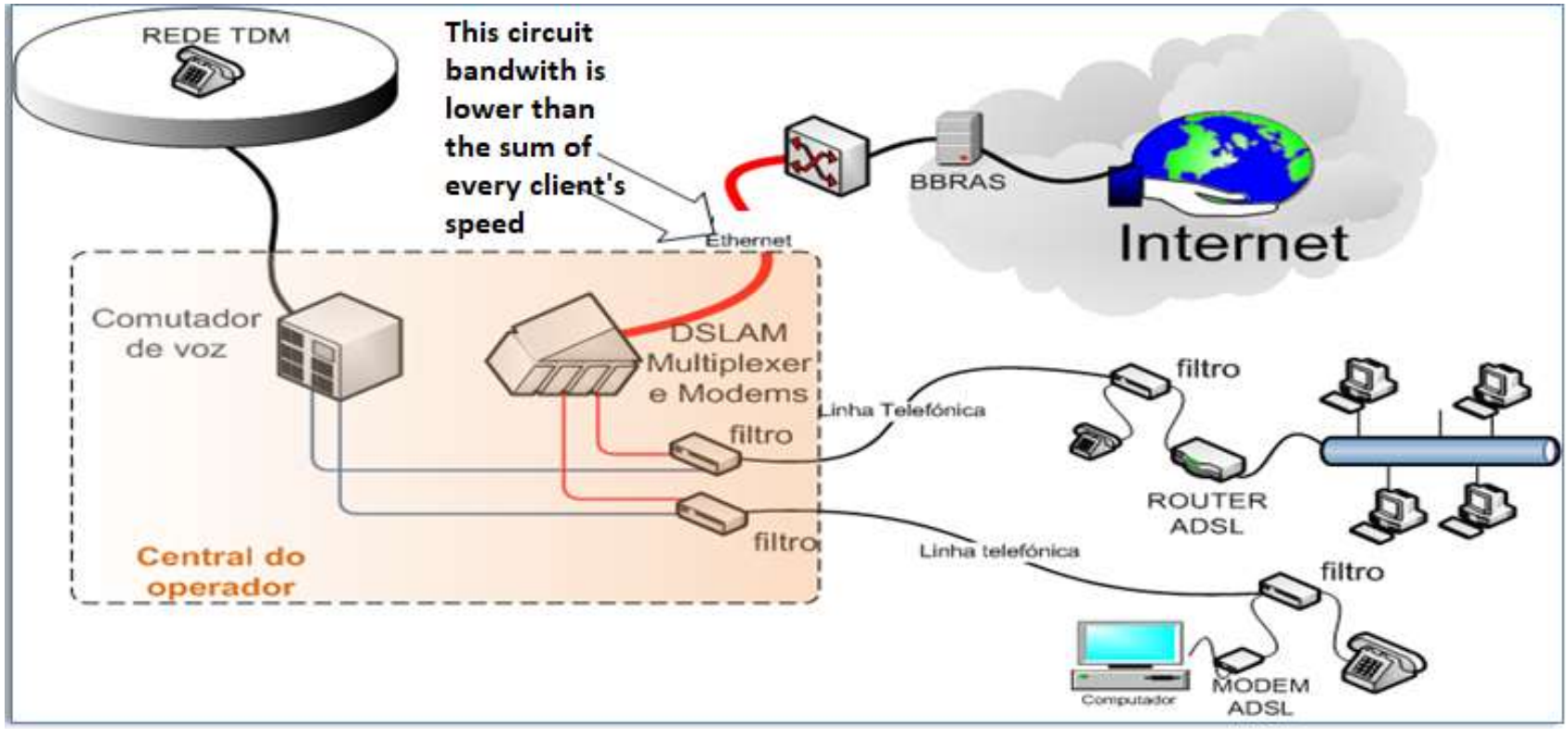
DSL ARCHITECTURE



TAXA DE CONTENÇÃO NO DSL

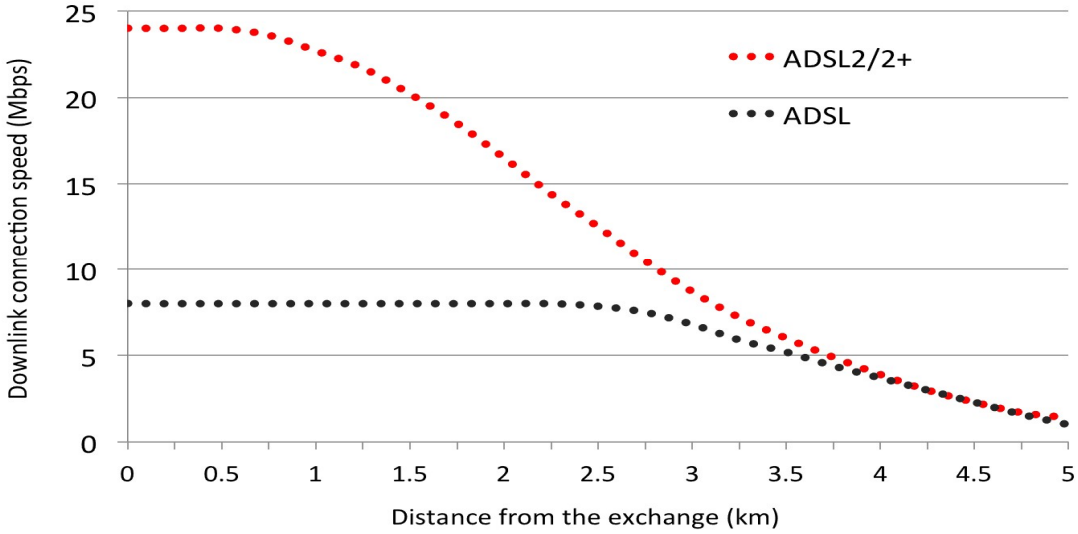
The link from the central to the Internet is shared with other operator users and has a bandwidth lower than the sum of everyone's speed.

Hence, the concept of containment rate: Ratio between the debit of the Internet link and the sum of the debit of all users. Typical values are 1:50, 1:20, and 1:10. This will affect the maximum effective speed of the clients!



DSL – Line ATTENUATION

The length of the telephone line have an important effect on the speed that can be reached on any ADSL. Attenuation and interference make impossible to use the highests carriers. Beyond 5 to 6 kms is impossible to provide internet service.



Source: https://www.increasebroadbandspeed.co.uk/2012/graph-ADSL-speed-versus-distance

DSL VARIANTS

Symetric(upload and download):

HDSL – High Bit Rate DSL

SHDSL – Single Pair High Speed Rate DSL

Asymmetric (download higher than upload)

ADSL – Assymetric DSL

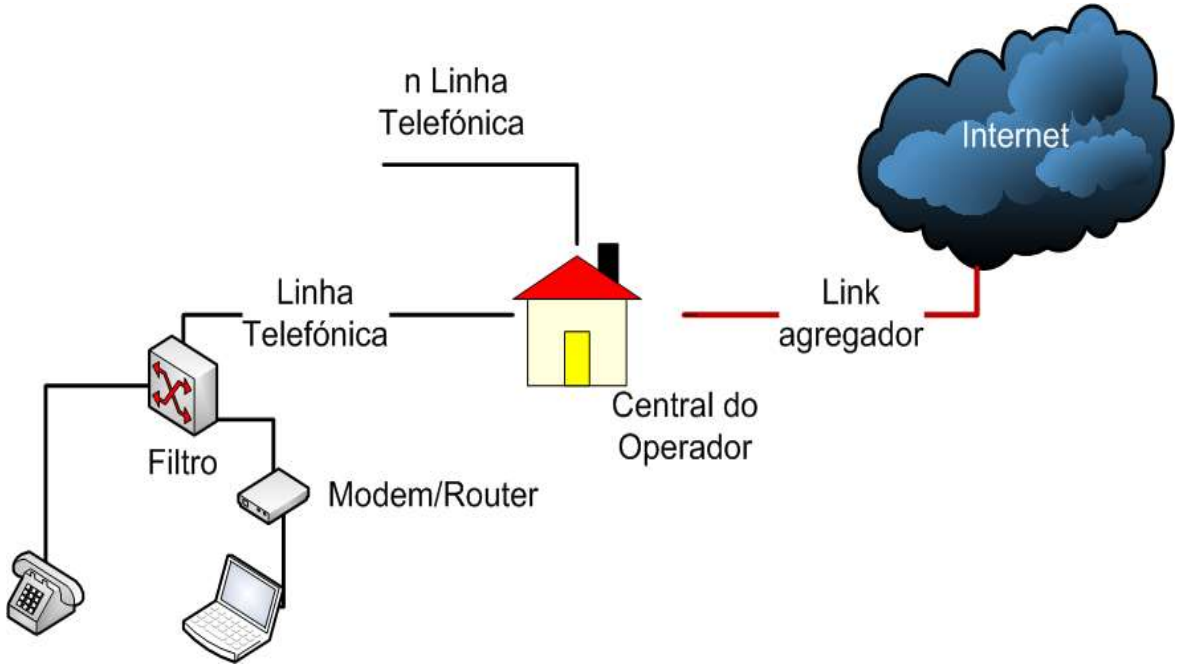
VDSL – Very High Speed DSL

ADSL

ADSL – Assymetric DSL technology allows simultaneous use of voice and Internet access in a pair of copper wire. 3 channels are defined:

- Base band (4kHz for traditional voice or 128Khz RDIS)
- Upload ADSL
- Download ADSL

To separate frequencies, you need to install a filter that delivers only the base band component to the telephone terminal:



ADSL VARIANTS

Within ADSL there are variants and evolutions that have determined different performance:

- ADSL up to 8Mbps/1Mbps

- ADSL2 up to 12Mbps/1 Mbps (best coding methods)

- ADSL 2+ 24Mbps/1 Mbps (uses 512 carriers instead of 256)

- ADSL 2+ Annex M - 24Mbps/2Mbps (more upload carriers)

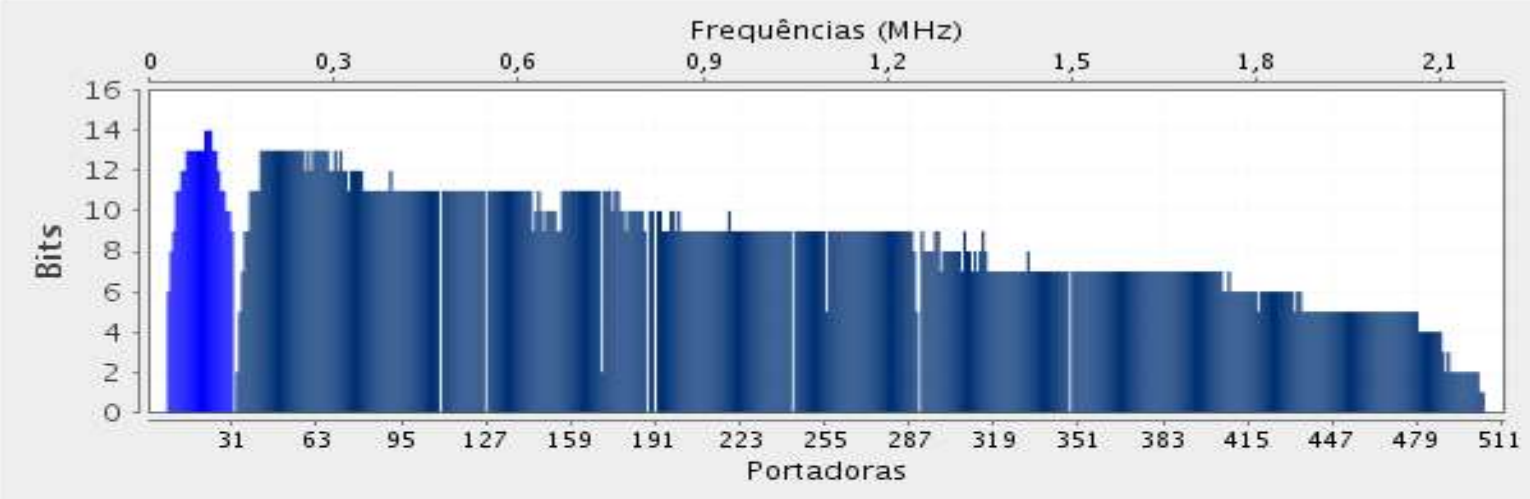
ADSL and ADSL2 use the frequencies up to 1.1MHz.

ADSL2 uses more sophisticated encoding modes than ADSL to make transmission more efficient and resistant to disruption. So it increased the download speed to 12Mbps.

The ADSL 2+ was able to use frequencies up to 2.2MHz and thus double the number of carriers.

ADSL

Example of spectrum in ADSL 2+ with 512 carriers available:



NOTA: clique no gráfico para aumentar/diminuir o seu tamanho.

RECOLHA ADSL									
Déb. Actual *(Kb/s)*		Déb. Máximo *(Kb/s)*		Atenuação *(dB)*		Mrg Ruído Act. *(dB)*		Mrg Ruído Obj. *(dB)*	
Up	Down	Up	Down	Up	Down	Up	Down	Up	Down
1 015	14 533	1 076	15 492	12	26	5	6	6	6

IPTV in ADSL

The TV distribution over telephone lines uses DSL technologies to provide IPTV.

Distant customers from the plant may not even have the TV service!

Limited output -> number of channels restricted to 2 or 3 (each encoded television channel occupies between 4 and 5 Mbps, so there is no space to more channels). ADSL bandwidth is shared by TV and Internet!

Every TV need a Set Top Box to choose the channel to receive!

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- DSL
- CATV networks
  - CATV network architecture
  - DOCSIS
- GPON
- Mobile Networks 4G - LTE and 5G

CATV

CaTV networks (Cable TV) were meant to broadcast television signals.

CATV networks, which reach the customer's home in coaxial cables, allow simultaneous dissemination of several dozen RF channels (injected into the domestic coaxial network).

The coaxial cable has a higher capacity than the copper wires of the telephone network at almost 500x (1GHz vs 2.2MHz) -> many channels available without needing Set Top Box!

CATV

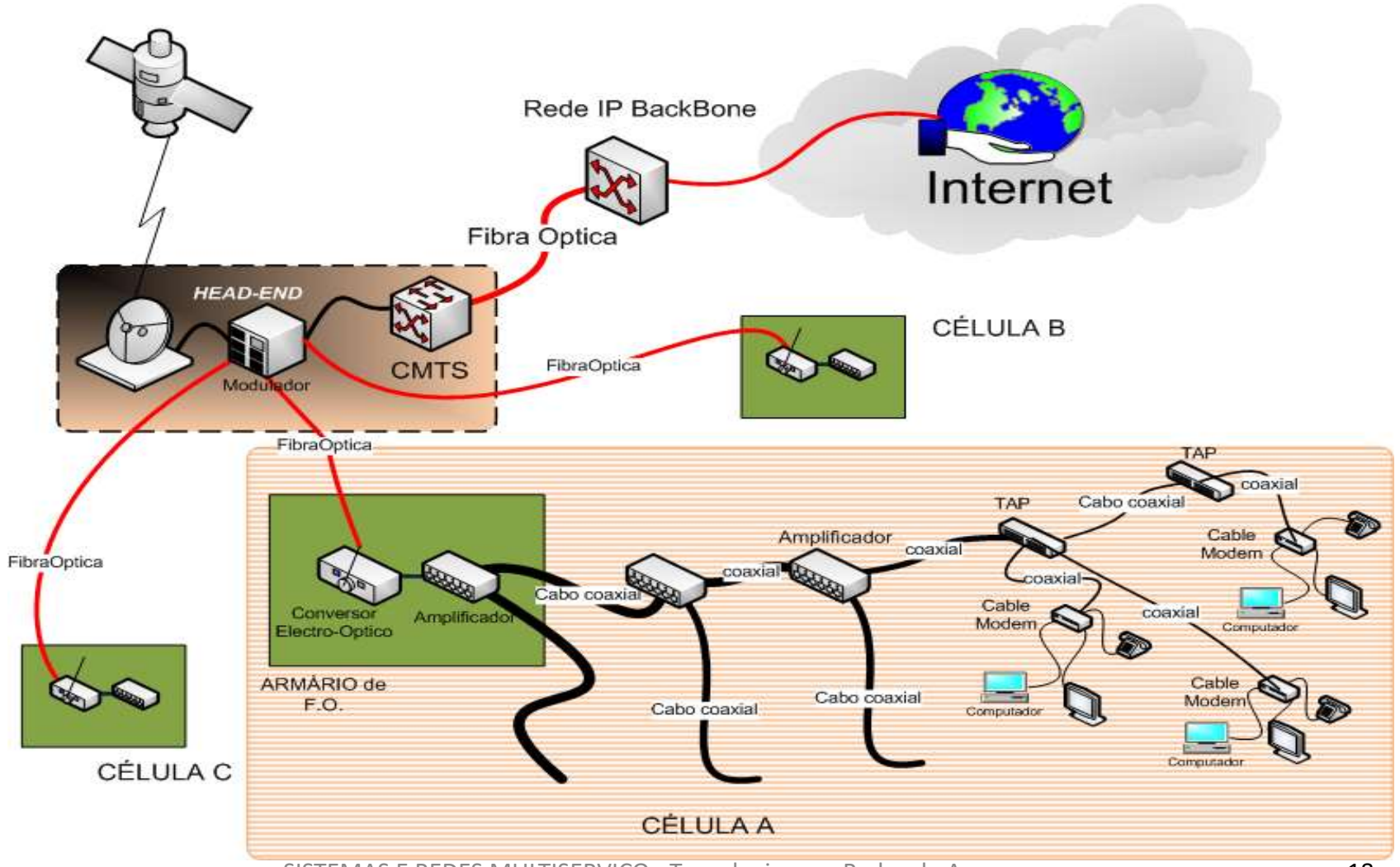
The generic structure of a CATV network is based on an area of a MAN (p.e. a city) divided in cells that cover a particular geographic area, typically 500 to 2000 houses.

The central point of the network is the Head-End (or Multi-Services Central) where the operator makes interconnection with the telephone network, Internet and data services.

From the Head-end, Fiber Optic cables break for each cell. In each of these there is a node where is an electro-optical converter that converts optical to electrical signal and injects it to the coaxial cable network.

In the coaxial cable television channels are sent modulated in frequency.

CATV ARCHITECTURE

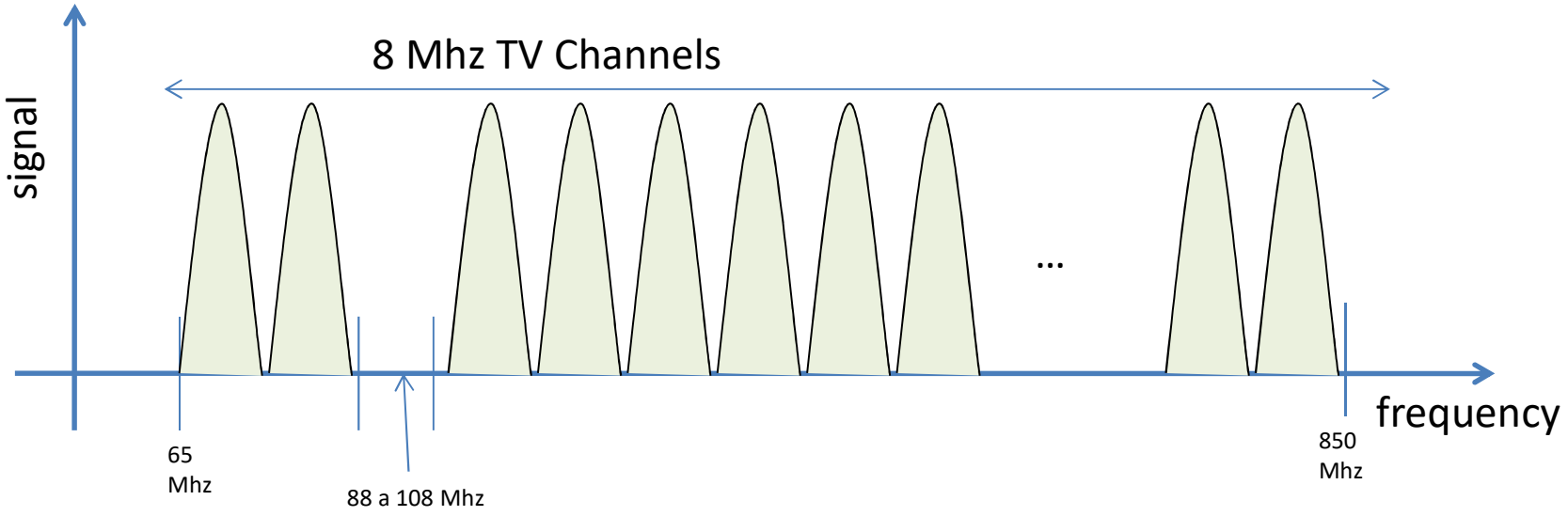


CATV Architecture

The CATV network is HFC – Hybrid Fiber Coaxial

In coaxial, the bandwidth of a typical cable used on the CATV network is about 1000Mhz (1Ghz).

Each RF analog signal TELEVISION channel occupies 6 to 8MHz in Europe (PAL system). Channels are multiplexed by FDM:



DOCSIS – INTERNET in CATV

- The introduction of data accesses on these networks implied a new technology called DOCSIS (Data Over Cable Service Interface Specification).
- DOCSIS was born in 1997 (version 1.0) and is currently in version 3.1 which, in addition to higher speeds, supports IPv6.
- DOCSIS objectives:
  - Take advantage of the available bandwidth (not used by TV channels) to provide data download at high speeds.
  - Uploading a network that until then was only download
  - Create a method of information privacy on a broadcast network

DOCSIS – INTERNET in CATV

DOCSIS solution: transmit data in available bands.

In the upload use the band from 5 to 65 Mhz that until then was free

In the download, bands not used by TV were used to place data. This channel is Broadcast!

DOCSIS Architecture

New equipment has emerged in the DOCSIS architecture:

In the operator central the Cable Modem Termination System (CMTS):

- modulate RF digital signals that will be transmitted via Fiber and Coaxial to the customer's home.
- DHCP server and authentication server functions.

On the client premises, a filter that separates the RF video component from the data and delivers it to the Cable Modem (CM).

There is resource sharing (the coaxial network acts like an hub) and individual performance is affected by the load produced by neighbors. (What about security??)

DOCSIS Architecture

In the downstream, the data (TV or Internet) is sent to all Cable Modems in broadcast.

- Each Cable Modem has a unique MAC-type identifier. CMTS sends this identifier in the packets to identify the recipient.

- There is a security mechanism that uses only known encryption keys from the CMTS to the client modem.

- The data exchanged between CMTS and CM allows the definition of the upstream channel, IP address, and security details.

DOCSIS

The standard has been developing in the aspects of data coding and protocols, allowing rapid growth of capacity:

Standard	Upload	Download	Technologies
DOCSIS 1.0 e 1.1	10.24 Mbps (8 uteis)	55 Mbps	QPSK and 16-QAM; Symbol Rate 2560 ksym/sec
DOCSIS 2.0	30.72 Mbps (27 uteis)	55Mbps	8-QAM, 32-QAM or 64-QAM; Symbol Rate 5120 ksym/sec;
DOCSIS 3.0	122.88 Mbps	Up to 400Mbps	Channel Bonding, Multicast, QoS and IPv6
DOCSIS 3.1	2Gbps	Up to 10Gps	4096 QAM; New CMTS; Channel Bonding increased

DOCSIS 3.0

Aggregates multiple channels for data transport (Channel Bonding).

- In the downstream, each 8Mhz channel (50 Mbps) can be aggregated to produce n x 50Mbps

- In the upstream can be aggregated at least 4 channels of 10Mbps, i.e. 40 Mbps

Other improvements:

- Increased Encryption Standard (AES)

- Increased upstream bandwidth to 85 MHz

- Increased downstream bandwidth up to 1 GHz

DOCSIS 3.1

- DOCSIS 3.1
  - Increase of 50% transmission capacity in the same bandwidth as DOCSIS 3.0 with 4096 QAM modulation methods and channel multiplexing
  - Upload from 5 MHz to 204 MHz; Download from 252 MHz to 1788MHz
  - Higher theoretical capacity: 10/2 Gbps with aggregation of more channels of 50Mbps
  - All information becomes digital, even TV channels -> changing terminal equipment (CM and CMTS)

DOCSIS

DOCSIS implements IP services. Thus, it can be used for Internet access, VPN, Video On Demand or IPTV channels. It is also compatible with IPV6.

An offer of RF channels delivered by coaxial to each Boxless TV (channel tuning on the TV itself) continues to be possible.

The use of paid channels is implemented on IPTV. The use of IPTV requires the existence of a Box on the client to request the desired channel.

Operators tendency to progressively implement more IPTV channels and less in RF to have more free channels to make Channel Bonding and thus increase the data output provided!

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Tecnologia DSL

CATV networks

GPON Networks

- FTTx Networks
- P2P Networks
- PON Networks
- Business model
- Future of PON networks

Mobile Networks 4G - LTE

Fiber Optic Networks

Classification of Fiber optic Networks in terms of the fiber endpoint:

FTTH – Fiber To The Home – the customer receives a fiber optic cable at home;

FTTB – Fiber To The Building – the operator delivers a fiber in a building and the distribution to the apartments is done in coaxial or copper, typically UTP cat5 or higher;

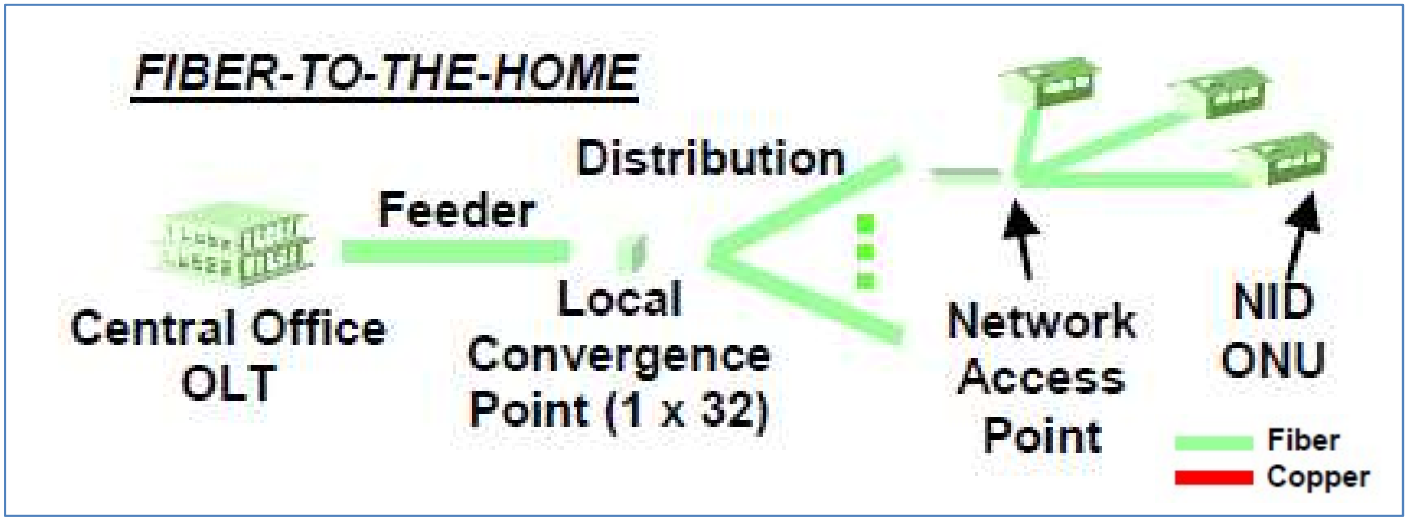
FTTC – Fiber To The Curb – Fiber comes to a street distributor from which coaxial cables or copper, typically UTP cat5 or higher for each house or building.

FTTN – Fiber To The Node – Fiber only reaches a central node from which copper or coaxial distribution is made to a particular coverage area (e.g. current CATV networks).

Fiber Optic Networks

FTTH – Fiber To The Home

- 100% Fiber optic network
- There may be resource sharing in network aggregator sections;
- Available bandwidth can reach the Gbps depending on the aggregation architecture used



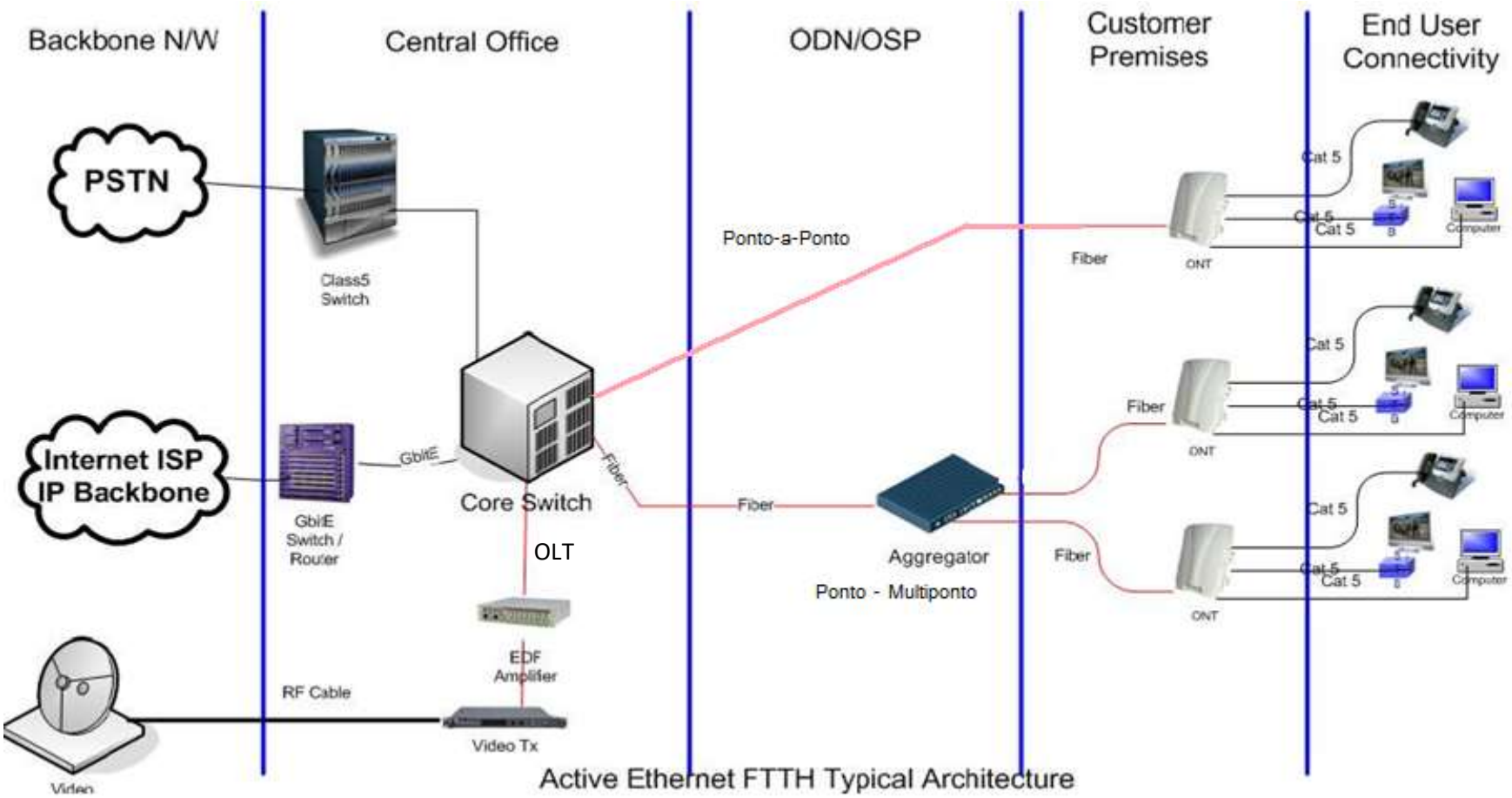
FTTH network ARCHITECTURE

Point-to-Point (P2P) - A direct fiber for each customer from the operator. Also called "home-run". It may have common sections but end up on fiber optic switches.

PON (Passive optics Network)- Fiber sections shared by each user with passive equipment on the network performing fiber splittage.

FTTH P2P

Components of P2P Fiber Optic Networks:



FTTH P2P

Components of P2P Fiber Optic Networks:

The CO (Central Office) is the fiber hub of all network users;

- Aggregates the TV, voice and Internet data received via core network and make switching to individual fibers.

- The OLT – Optical Light Transmiter is a core switch that has a laser for each fiber or customer. Up to 768 customers per OLT.

Between the CO and the user there may be intermediate aggregator switches. Because they are active equipment, P2P networks are also called Active Switched Optics Networks (ASON) or Active Ethernet optic networks (AEON).

On the client premises there are the ONTs – Optical Network Terminal - whose function is to gateway between optical and electrical signals and also separate the components of voice, Internet, RF TV and IPTV.

FTTH P2P

Performance of P2P Fiber Optic Networks:

- Upper distances (up to 80 km);
- Client Bandwidth only limited by transmitter technology and optical receiver;
- Typically operates on Ethernet technology;

Advantages

- They are simpler networks to operate as each user receives their fiber section and no resource sharing is required.
- The failure of a laser only affects a customer!
- Also the individualization and differentiation of services per client becomes simpler. Hence also greater security of each other's information.
- Since there are no losses in splitters, the distances are much higher than xPON networks (up to 80 km).

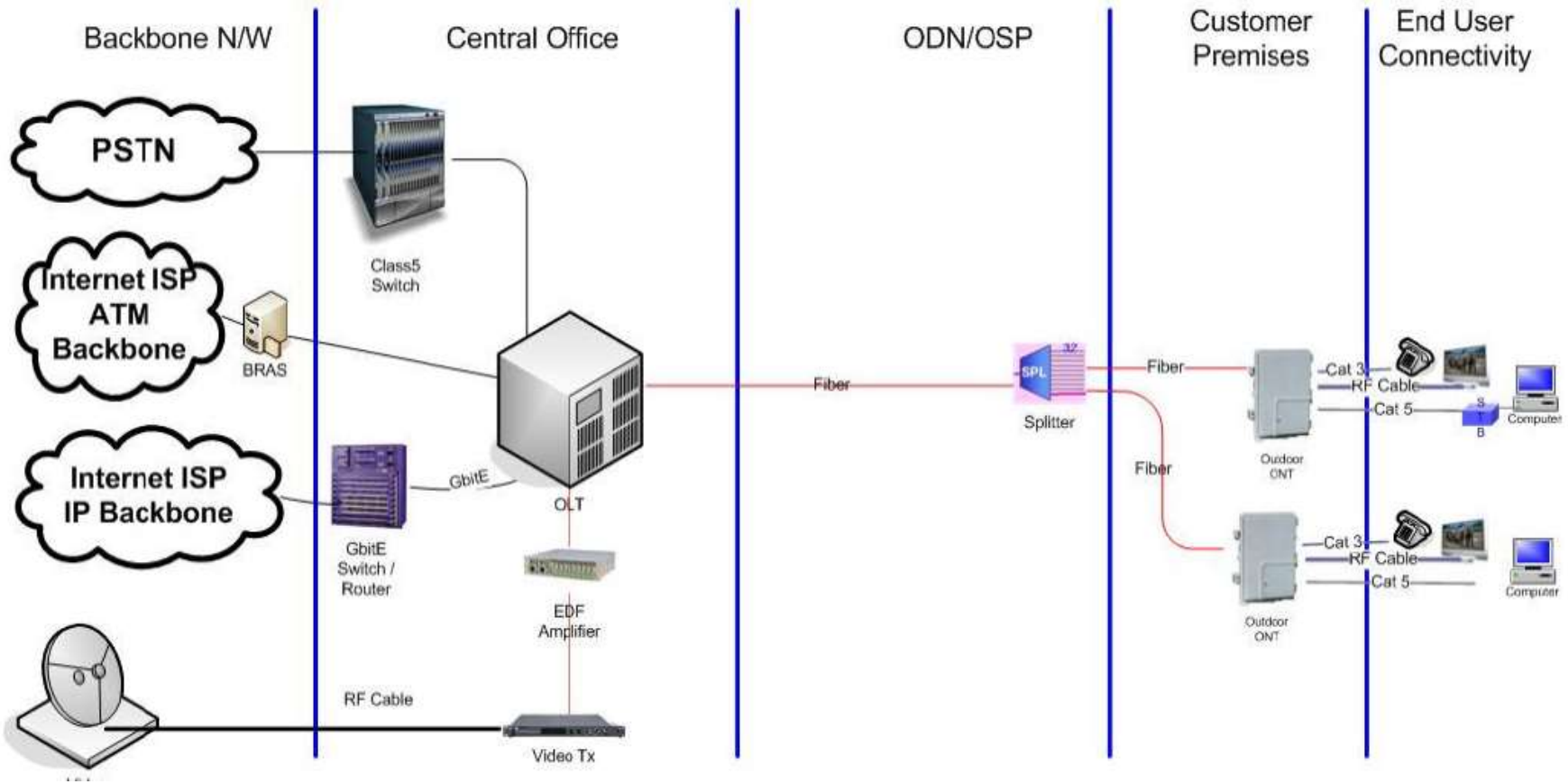
FTTH P2P

P2P Fiber Optic Networks Disadvantages

- The number of customers served is limited by active equipment.
- In the central, there will have to be a fiber termination and a laser equipment for each client, implying greater need for space.
- If switch are chosen in the network splits, there will need to be a "cabinet" of distribution with power supply and a careful study of their placement.
- It implies more costs
- The cost with Fiber is higher.

FTTH PON

Components of PON Fiber Optic Networks:



FTTH PON

Components of PON Fiber Optic Networks:

- The Central Office (CO), is the point where a fiber optic to the network comes from;
  - Aggregates the TV, voice and Internet data received via core network and will deliver it fiber.
  - The OLT – Optical Light Transmiter is unique for all users in the same cascade.
  - Supports up to 16,384 customers.
- Between the CO and the user there are only passive fiber splitters. As they are passive, these networks are called PON - Passive optics Network
- On the client are the ONT - Optical Network Terminal whose function is to gateway between optical and electrical signals and also separate the components of voice, data, RF TV and IPTV.

FTTH PON

PON components:

- Passive equipment split the fiber bandwidth by multiple users.
  - There are 1:2, 1:4, 1:8, 1:16 and 1:32 splitters.
  - Signal losses (attenuation) are proportional!
  - There may be cascading splitters but typically each CO output fiber only feeds a maximum of 64 or 128 users.
  - They don't do any signal filtering. Act by optical reflection methods.

FTTH PON

Medium Access Control in PON Networks:

- In the download, all users receive the same signal – need for encryption of data communications (on TV is not necessary, because ...?);
- In the upload it is necessary to ensure that there are no two ONTs to transmit at the same time!
  - Because CSMA/CD (Ethernet) techniques are not applicable due to the distance, in PON can be used:
    - TDMA - time split
    - WDMA - division by wavelength/frequency

FTTH PON

PON Disavantages

- They are more difficult to install networks as, although it is a fiber to come out of the concentrator, there is additional work of splitting fiber.
- The laser failure in CO affects all customers of the same cascade!
- Individualization and differentiation of services per client is more complex with features of time or wavelength multiplexing.
- Hence also more security system needs. Due to losses in splitters, distances are lower than P2P networks (up to 20 km).

FTTH PON

PON: Avantages

- In the central, there is only a need for one laser per cascade (but there is multiplexing equipment for managing the signals of each user).
- The cost with Fiber is lower.
- Because splitters are passive (layer 1) support any type of transmission technology (packets, TDM, or WDM). They can even migrate between technologies without fiber exchange.
- Multicast techniques can be used in download (useful for TV broadcasting)

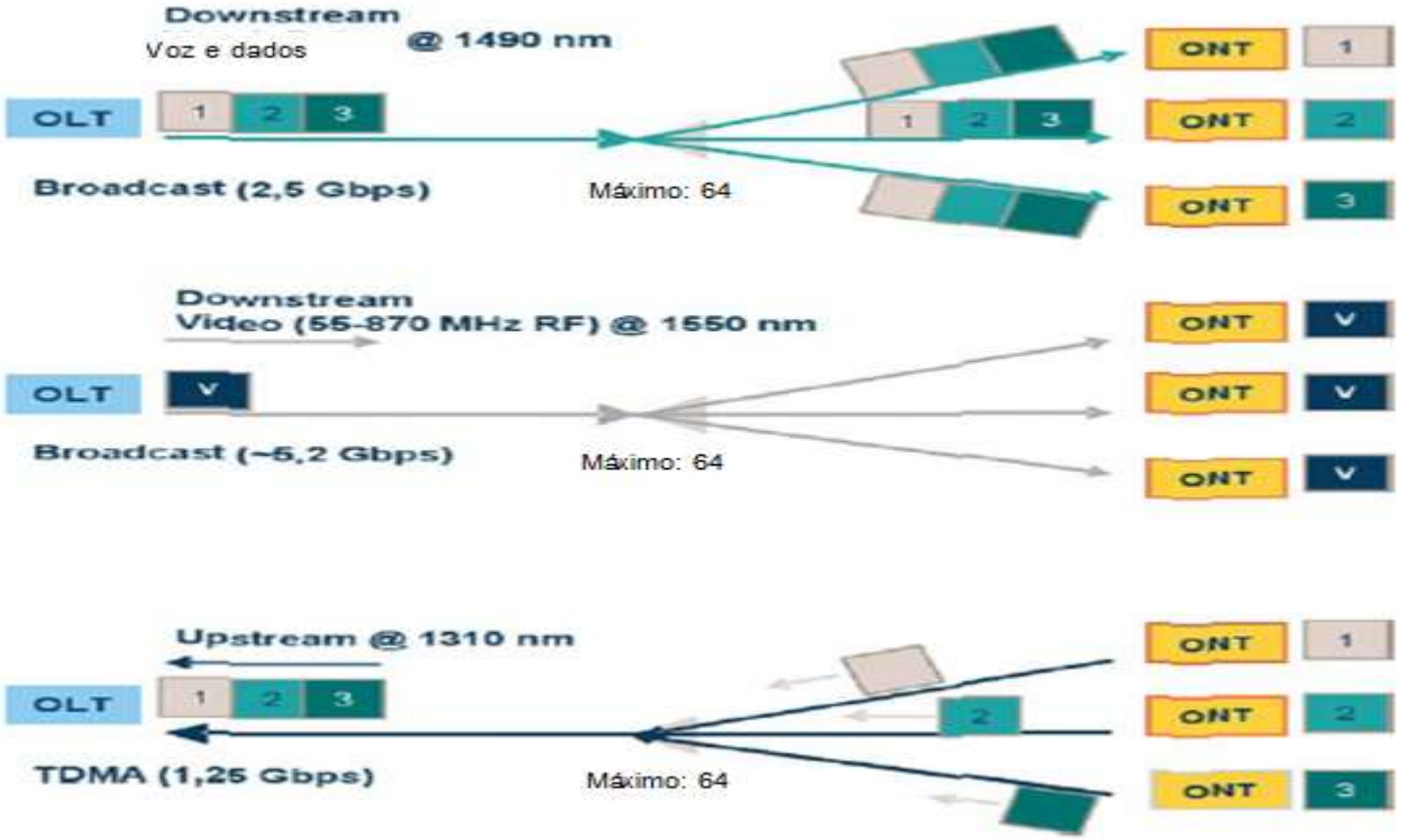
GPON

Currently, in Portugal, in the fiber networks of operators coexist two generations GPON:

Parâmetro	GPON	XG-PON / XGS-PON (aka 10GPON)
Debit data at the OLT output	2,5/1,2 Gbps	10/1,2 Gbps ou 10/10 Gbps
Customers in the same cascade	64	128
Max of splitters in cascade	4	
Max Distance	20Km	
Encryption	128 bits AES	

GPON

Example of multiplexing of TV services, data and VoIP in GPON (in the same fiber):

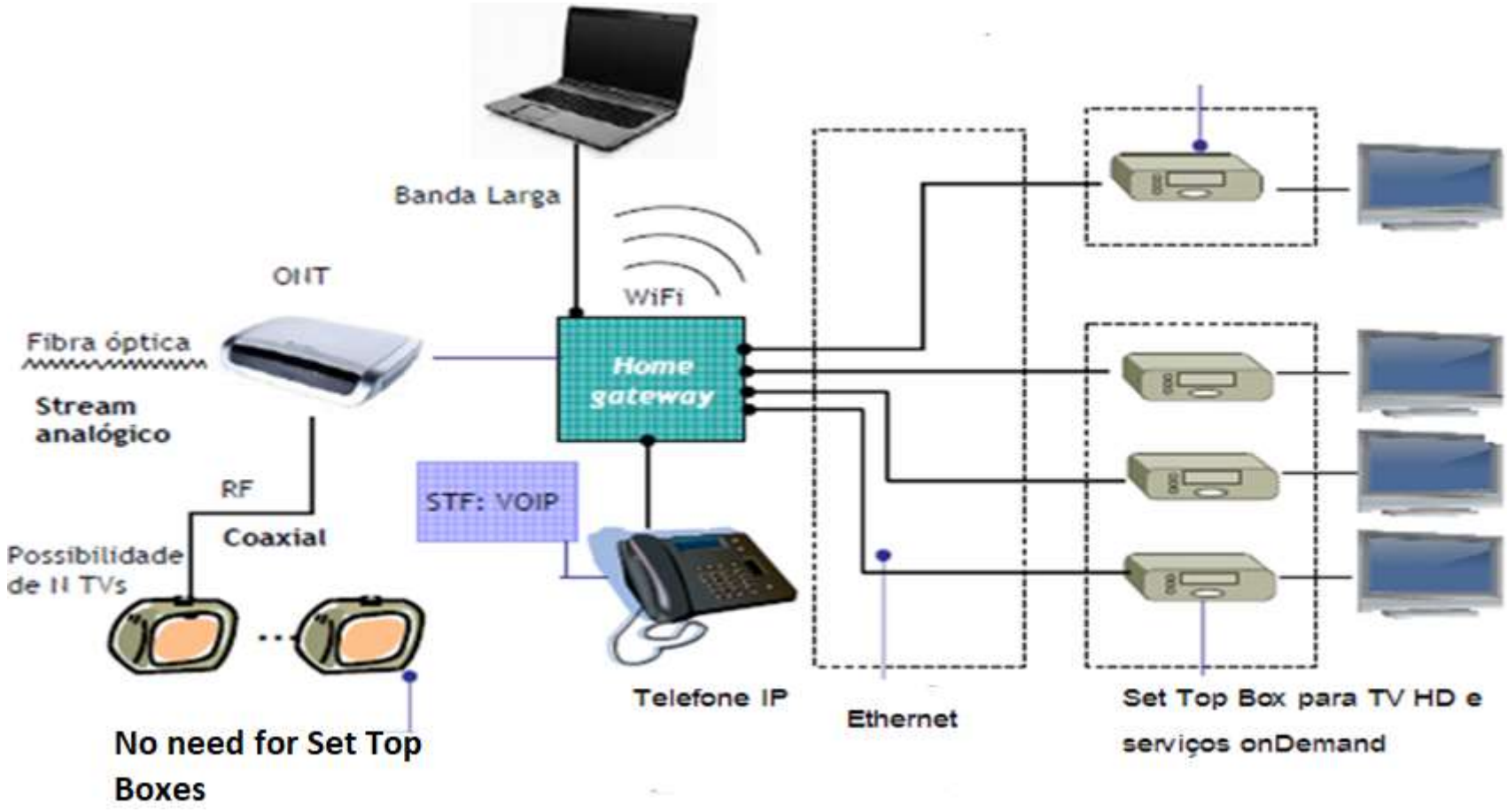


COMMERCIAL MODEL of GPON NETWORKS

- **TV**
  - Provision of High Definition Television format (HDTV) on multiple televisions simultaneously.
  - More TV streams and more HD streams
  - Provision of a TV RF service for coaxial with no need of Set Top Box allowing you to serve all client TVs (ONT converts the optical signal into RF capable of being injected into the coaxial network from home)
- **Internet**
  - Higher bandwidths in Internet access – standard 1Gb download and 200 Mbps upload offers but able to grow without fiber exchange!
- **Phone**
  - service via VOIP (Voice Over IP)

MODELO COMERCIAL REDES GPON

Client's premises:



PON evolution

Fonte: "**New FTTH-based Technologies and Applications - A White Paper by the Deployment & Operations Committee" ,** José Salgado (PT Inovação), Rong Zhao (Detecon International), and Nuno Monteiro (PT Inovação), www.ftthcouncil.eu

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- GPON
- Mobile Networks
  - Evolution of mobile networks
  - 4G - LTE
  - LTE Architecture
  - 5G overview

EVOLUTION OF MOBILE NETWORKS

1G - Analog Network	1 voice channel- Mobile Telephony Driver: mobility; Problems: safety and efficiency
2G - GSM	1 voice channel / data up to 9.6kbps Mobile Telephony, Messaging(SMS), Modem /Alarms Driver: massification, security; Problems: low debit
2,5G GPRS/EDGE	Data from 12kbps to 128kbps - M2M, Messaging (MMS), mobile Internet Driver: data access; Problems: WAP failed
3G - UMTS/HDSP	Voice and data simultaneously - Mobile telephony, mobile Internet and access to private data networks (APN/VPN) Driver: Internet Access; Problems: lower-than-expected debits
4G - LTE	Voice (IP) and data simultaneously - IP mobile telephony and high-speed mobile Internet, access to private data networks (APN/VPN) Driver: Fast Internet; low latency; Problems: voice remained in 3G

LTE - 4th GENERATION

On the current mobile network, the most advanced technology in use is called LTE- Long Term Evolution (known as 4G)

It is a 3GPP project with the objectives of:

- Ensuring the competitiveness of mobile networks in the future
- Track user needs
- Improve Performance at a lower cost
- Reduce complexity
- Be easily integrated with other systems such as wi-fi or wimax

LTE ARCHITECTURE

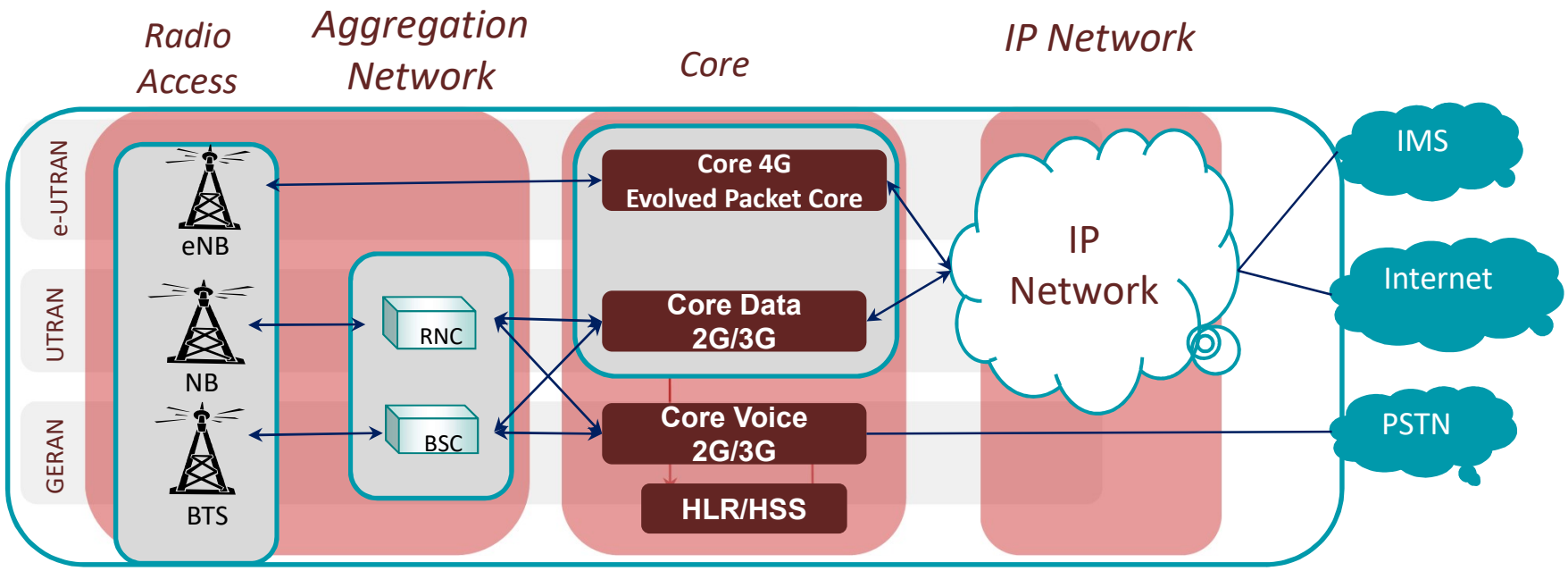
LTE- Long Term Evolution implied the development of:

- New user equipment (EU)
- New Radio Access Network (E-UTRAN)
- New All-IP Core (Evolved Packet Core)

LTE – Evolved Packet System

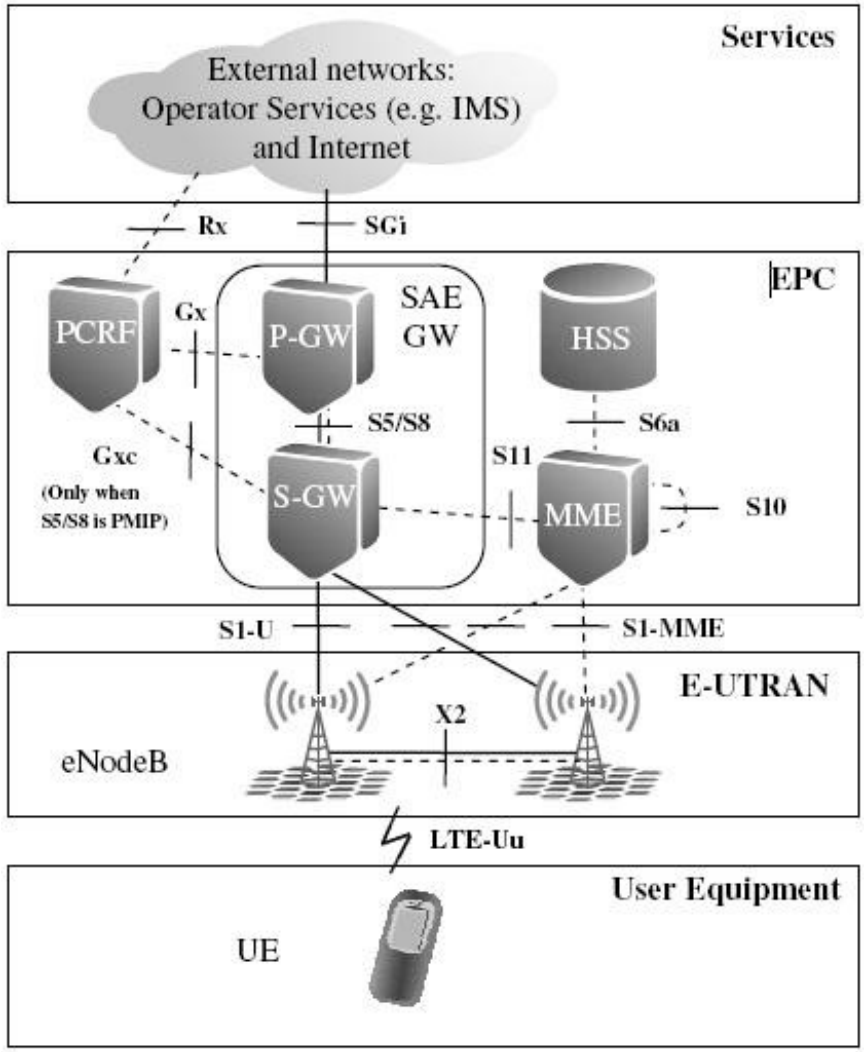
- The EU is the user terminal (p.e. smartphone) that connects to the radio network.
  - Allows access to various services: voice, data, internet, video, pay-tv, etc.
- E-UTRAN is the visible face of the network for the user and consists of radio network access points, called eNode-B.
  - The biggest evolution of this segment is that it is more simplified (on 2G and 3G networks there was an aggregation level) and no longer acts by switching circuits but in switching ip packets.

MOBILE NETWORK ARCHITECTURES



BTS - Transceiver Station Base - Network element responsible for wireless communication in GSM using GERAN radio technology – GSM Edge Radio Access Network
BSC - Base Station Controller - Element responsible for controlling multiple BTS
NB – Node B – at UMTS is the equivalent of GSM Base Stations (BTS); uses UTRAN radio technology - Universal Terrestrial Access Network
RNC - Radio Network Controller (UMTS /NB) - Element responsible for the control of several NB
eNB- Evolved NB - nb evolution- responsible for wireless communication in 4G/LTE using E-UTRAN technology - Evolved Universal Terrestrial – unlike GSM and UMTS technologies, in the LTE eNB have soaked control functions.

LTE – Evolved Packet System



EPC is a new fully IP core network:

- Mobility Management Entity (MME): authentication, security, mobility management and user profile, connection and service authorization.
- HSS (Home Subscriber Server): User Registration Database
- S-GW (Serving Gateway): routing data packets between the LTE network and other technologies such as 2G/3G
- P-GW (Packet Data Network Gateway): is the edge router between EPC and external packet networks. Assigns IP addresses to users
- PCRF (Policy and Charging Resource Function): QoS

LTE

Some technical features of The LTE:

- There is always resource sharing between users either in upload or download;
- Use of MIMO technology with 4 antennas – use multi-antenna capabilities simultaneously.
- SIP protocol for user location management and control of voice, data or multimedia communications.
- Operators still don’t transport voice in 4G. It will be in IP: VoLTE!

LTE

The speeds vary depending on:

- Channel bandwidth
  - Channels with 1.4, 3, 5, 10, 15 or 20 MHz are possible
- Radio channel conditions
  - eNB selects modulation depending on signal quality
- MIMO
  - Depending on the location, there may be 2x2 or 4x4

The final value can range from just under 1Mbps to about 400Mbps. This value is shared by users in the same area.

See: https://www.cellmapper.net/4G-speed?lang=pt

LTE

Other features:

- Cells about 2Km radius (on average)
- 200 active users in cells with 1.4MHz or 3MHz LB channels
- 400 active users in cells using 5MHz channels up to 20 MHz
- Maximum user latency at the end of the radio network: 10 ms
- Ensure performance up to 120km/h and a minimum at least up to 350km/h
- Ensure performance in cells up to 5km radius with minimal degradation in cells of 30Km.
- Idle time until connected: 50 ms

FUTURE OF MOBILE NETWORKS: 5G

The next mobile generation is the 5G supported in the 5G New Radio architecture (5G-NR)

- Maximum debits of 20Gbps
- Lower latencies (from 1ms)
- Lower energy consumption
- Specification for IoT

Implementation is expected from 2019. Two strands:

  - Fixed wireless access – for the provision of services equivalent similar to fixed network;
  - Mobile services

FUTURE OF MOBILE NETWORKS: 5G

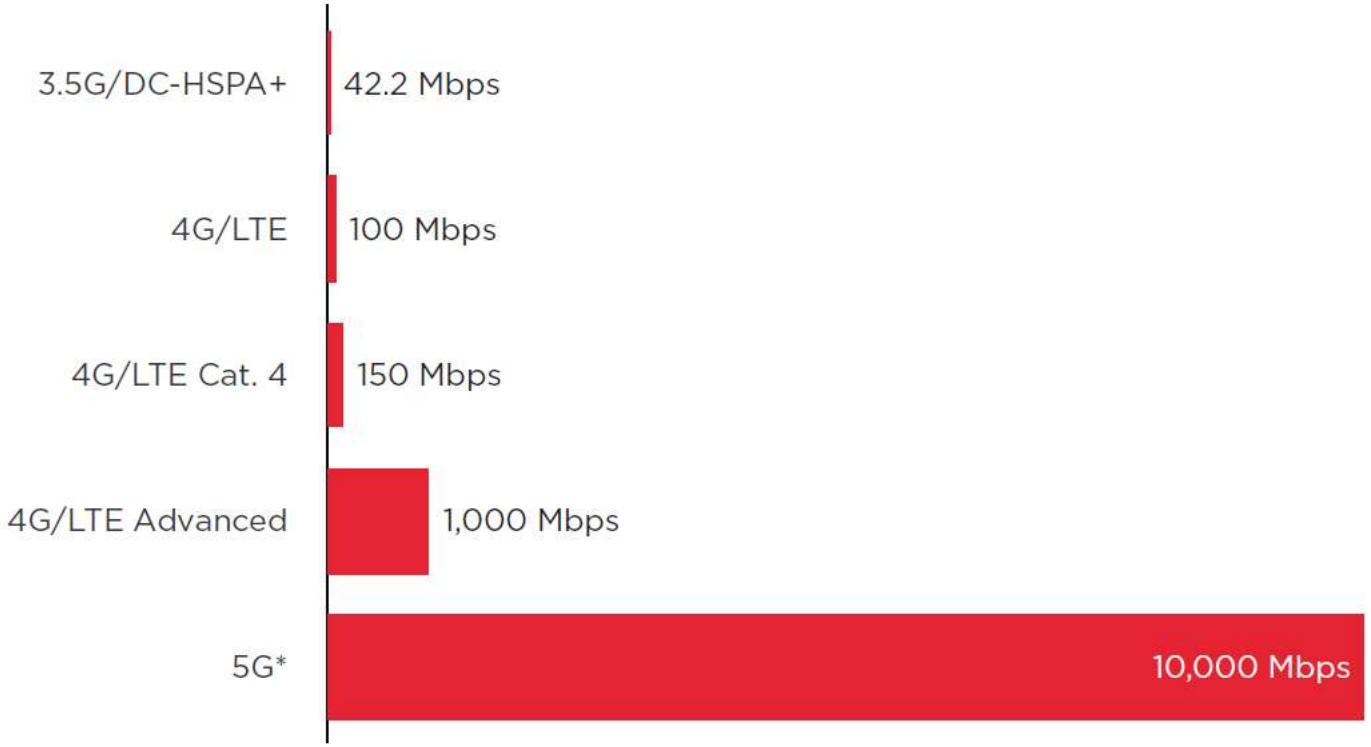


Figure 2: Maximum theoretical downlink speed by technology generation, Mbps
(*10 Gbps is the minimum theoretical upper limit speed specified for 5G)
Source: GSMA Intelligence

FUTURE OF MOBILE NETWORKS: 5G

Some 5G technological innovations:

- Greater need for radio spectrum
  - millimetric waves > 24 GHz - higher output but lower range!
  - 400 cells per 100Km2 (500mt radius) -> use lampposts, p.e.
- Connecting antennas with fiber optic network (e.g. 10GPON) to support the desired output.
- Massive-MIMO
- More advanced coding techniques (OFDMA)

FUTURE OF MOBILE NETWORKS: 5G

Massive MIMO:

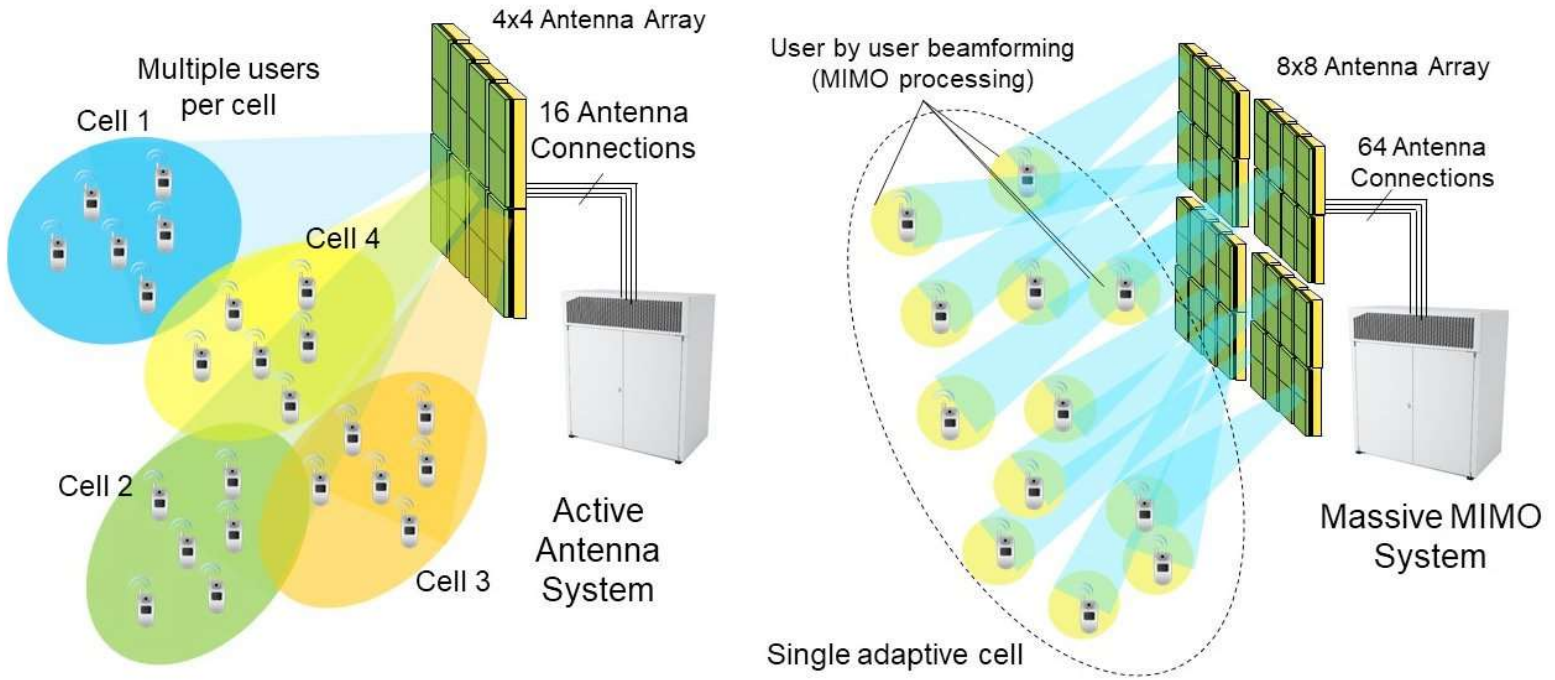


Image from: "https://twitter.com/edncom/status/951582113459064832"

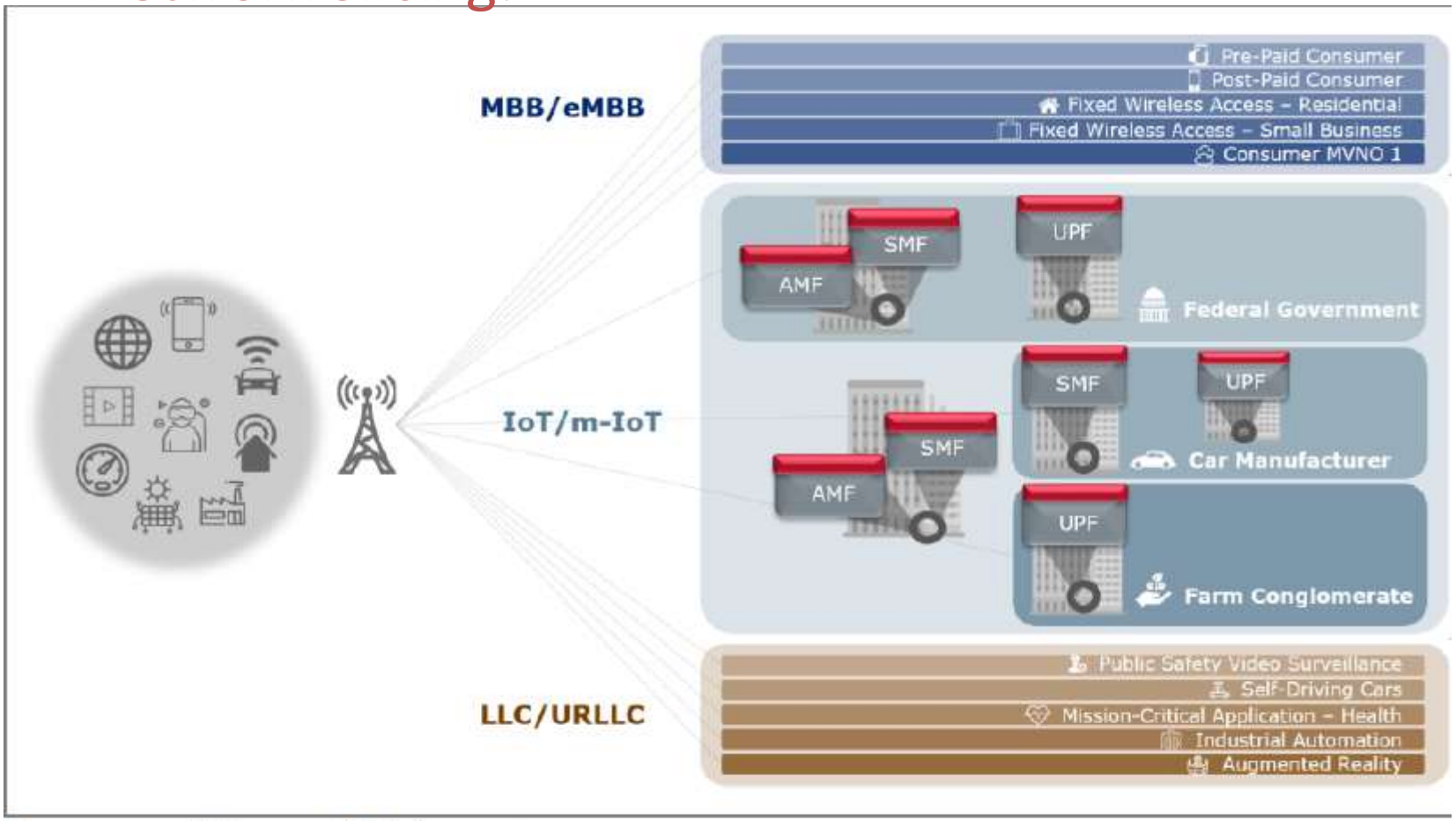
FUTURE OF MOBILE NETWORKS: 5G

The three technological pillars to which the 5G network should respond:

- eMMB – enhnaced Mobile Broadband
  - Applications with large volumes of traffic (up to 20Gbps), e.g. 4K Video, Gaming, Video surveillance, Fixed Radio Access
- mMTC - massive machine-type communications
  - IoT type mass communications (up to 1 million devices) with low output and power consumption
- URLLC - ultrareliable and low-latency communication
  - Low latency communications (up to 5ms) and reduced losses, e.g. critical emergency communications, location, autonomous cars, etc.
- This division is achieved through Network Slicing – virtual division of the radio network in order to ensure different behaviors for different applications!

FUTURE OF MOBILE NETWORKS: 5G

– Network Slicing:



Source: Affirmed Networks

TECHNOLOGIES IN ACCESS NETWORKS

Doubts?